A Policy Menu for Cleaner Production: Or What Governments Might Do to Promote Cost-Effective Reductions in the Pollution, Energy, and Materials Use Intensity of Industrial Production?

by

Michael T. Rock
Senior Economist
Winrock International

Prepared for Richard Sheppard
of the United States-Asia Environmental Partnership

April 1998

Executive Summary

Evidence abounds that sustainable industrial growth in the developing market economies (DMEs) of Asia requires lowering the pollution, energy, and materials use intensity of industrial production. But how is this to be accomplished? A simple analytical model is developed to answer this question. The model demonstrates that getting environmental, economywide, industrial, and technology policies right is critical to cost-effective pollution, energy, and materials intensity reduction.

With respect to environmental policy, two issues matter. First, it is important to develop a competent and tough environmental regulatory agency with clear legal authority to set quantitative environmental goals. Such an agency must also have a credible capacity to enforce compliance by reluctant polluters. Beyond this, environmental policy must focus on: (a) integrated pollution control that emphasizes continuous improvement and preventing pollution; (b) public disclosure of plant- and firm-level pollution performance; (c) greater cooperation among polluters, regulators, and the science and technology community; (d) affording greater flexibility to firms in how pollution intensity reduction targets are met; and (e) use of market-based instruments to meet environmental objectives.

Economywide, sectoral, and industrial policies for cost-effective pollution intensity reduction should emphasize: (a) full cost pricing, including all social costs, for all forms of energy and materials use as well as for the manufacture, use, and disposal of all products; (b) economically efficient concession agreements between governments and resource-extractive industries; (c) market-oriented exchange rate and trade policies for achieving efficient energy use in all industries and for achieving efficient (international best practice) materials use for all materials-processing activities; and (d) the integration of environmental considerations in industrial policies. Experiences in Singapore, Taiwan, and Malaysia suggest that this integration can be done by fostering collaboration among environmental agencies, investment promotion agencies, the science and technology community, and commercial banks.

But none of this will work unless individual plants, factories, and firms have the capacity to manage production at international best practice levels and to manage technical change, particularly that associated with the acquisition and adaptation of new imported technology. Available evidence suggests that there is enormous variability in the capacity of firms in developing countries to do this well. Yet, unless this happens, firms are unlikely to be able to engage in cost-effective pollution intensity reduction by: (a) carrying out better housekeeping practices and minor process innovations that prevent pollution; (b) "stretching" existing plant, equipment, and technology by substantially modifying it to reduce pollution, energy, and materials use; and (c) correctly evaluating the pollution, energy, and materials intensity of "new" imported plant, equipment, and technology.

Because of this, governments need to promote the development of firm-level production and technological capabilities, including those associated with environmental improvement. They can do this by promoting high stable growth and the export of manufactures. They can also do this by either promoting the development of large firms that can internalize the externalities associated with technological learning (the Korean experience) or by relying on a collaborative relationship between business and government to reap these externalities (the Taiwanese experience).

In either case, governments must also invest in national technical capabilities-building by supporting education, particularly engineering (and environmental engineering) education, and by investing in institutions that can test materials, inspect and certify quality control standards (including environmental standards such as ISO 14000), calibrate measuring instruments, and provide difficult to obtain information (including in the area of clean technologies). Because of the unique problems of small and medium enterprises (SMEs) governments might also wish to build environmental considerations into already existing or new and to be developed highly targeted linkage programs between SMEs and foreign firms with international best practices.

One other issue matters. Knowledge in each of these areas is extremely limited. Because of this, it is important to proceed by trial and error and to engage in a substantial applied research program. Without this research program, there is enormous potential to waste scarce resources and to miss an important opportunity to assist the DMEs in Asia in making a transition to a less pollution, energy, and materials intensive industrial growth path. This would be extremely unfortunate.

I. Introduction

The developing market economies (DMEs) of Asia, like their counterparts in the rest of the world, have pursued economic growth (albeit more shared growth) at the expense of the environment.[1] This is particularly true of the industrial sector, where growth has been accompanied by an increasing pollution load and rising pollution intensities (Brandon and Ramankutty, 1993:67, 74).[2] Because the scale of industrial activity in Asia's DMEs is expected to increase for some time[3], it is clear that sustaining environmental quality requires lowering the pollution, energy, and materials use intensity of industrial production.[4]

The fundamental question addressed here is: How might public policy be used to promote industrial production and consumption with lower pollution, energy, and materials use intensities? Because so little is known about what drives the actual industrial-environmental behavior of manufacturing firms in Asia, what follows is decidedly theoretical and exploratory.[5] The focus is on developing a simple, but powerful, analytical model that makes possible the identification of a menu of possible policy options.

---

[1] Singapore is a notable exception (Rock, 1997c).

[2] It is also true of degradation of the resource base and of environmental quality in urban environments where the combination of growing industrial pollution and inadequate treatment of human wastes and garbage and vehicular pollution is undermining urban environmental quality (Brandon and Ramankutty, 1993: chaps. 3, 6).

[3] For a specific example, see World Bank (1994:74-84).

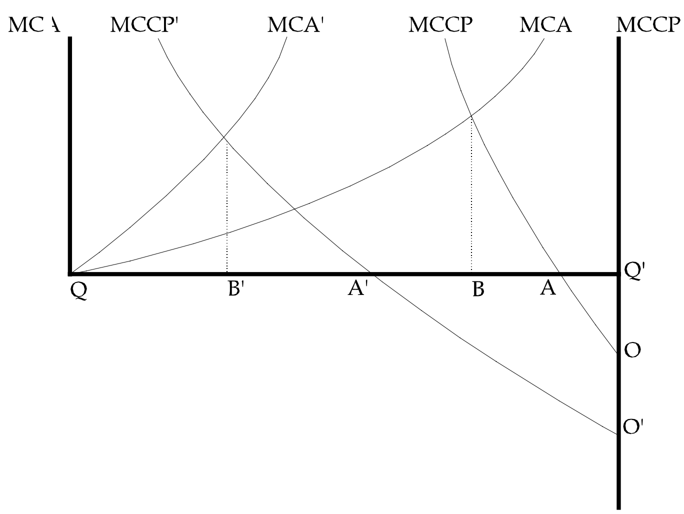
[4] Pollution, energy, and materials use intensities are defined in physical units per constant dollar of value added.

[5] For discussion of what is known see Hettige et al, 1996. They demonstrate that plant-level pollution abatement behavior is driven by characteristics of plants (size, age of plant, sector of plant, profitability/productivity of plant, and ownership of plant), community pressure, and public disclosure of a plant's environmental performance.

II. The Simple Analytics of Reducing the Pollution and Resource Use Intensity of Industrial Production

The analytics of cost-effective reductions in the pollution, energy, and materials use intensities of industrial production can be demonstrated by way of a simple diagram (figure 1) adapted from Rock (1997a). Let QQ' equal a desired reduction in the pollution intensity of industrial production for a firm, industry (sector), or economy. QQ' might reflect either an absolute reduction in pollution intensity (measured in pounds of pollution per unit of value added) or a percentage reduction in pollution intensity needed to sustain a given level of ambient environmental quality.[6] The left vertical axis measures the marginal dollar cost of reducing pollution intensity (MCA) through traditional pollution abatement (end of pipe expenditures). The curve MCA as drawn (rising from left to right) reflects the traditional rising marginal cost of abatement associated with increasing reductions in pollution intensity through post-pollution treatment. The right vertical axis measures the marginal dollar cost of reducing pollution intensity through pollution prevention and what industrial ecologists refer to as "dematerialization" (Warnick, Herman, Govind, and Ausubel, 1996). This curve is labeled (MCCP) to refer to the marginal cost of cleaner production. It too is reflected in an increase (but from left to right) of the marginal cost of reducing pollution intensity by cleaner production.

Figure 1



There are several important differences between the MCA curve and the MCCP curve. First, to reiterate, MCA reduces pollution intensity by treating pollution after it has occurred, while MCPP prevents pollution by, among other things, substituting less-polluting inputs for more-polluting inputs, improving energy and materials use efficiencies, and recycling energy and materials. Normally, these cleaner production alternatives are brought about by some combination of better "housing keeping" practices, minor process modifications, or fundamental technical innovation in industrial production processes.

Because of this, reductions in pollution intensity achieved by dematerialization and pollution prevention, or what is referred to here as cleaner production, are different from those

6 If the scale of industrial activity increases, the size of QQ' may have to be expanded to sustain a given level of ambient environmental quality.

achieved by abating pollution through end of pipe treatment.[7] For one, end of pipe treatment is always cost-increasing while not all cleaner production is cost-increasing.[8] This is depicted in figure 1 with an MCCP curve whose origin lies below the zero axis. This part of the curve (represented by OA and area OQ'A) reflects declines in pollution intensity that can be attributed to declining energy and other materials use intensity or cleaner production that “pays.” Second, end of pipe treatment is almost always a derivative of environmental regulatory policy, while cleaner production can result from regulatory policy and/or from the normal competitive pressures among firms in an industry; changes in the relative prices of energy and other materials inputs; the pace, pattern, and rate of diffusion of technological change; and the economics of recycling. This means that “dematerialization,” “pollution prevention,” and cleaner production need not be driven solely by regulatory policy. As will be argued below, understanding this and appreciating how regulatory and other policies can reinforce these effects is critical to the design of public polices aimed at reducing energy and materials use intensities. One example of this should suffice.

In the context of the DMEs of Asia, dematerialization and pollution prevention effects that “pay” might well represent declines in energy and resource use intensities associated with new (and cleaner) investment.[9] Given the volume of expected new investment relative to the size of the existing capital stock in the DMEs in Asia, these effects could be substantial.[10] If this proves to be the case, it suggests that developing country governments in Asia might need to pay more attention to new investment policies; how industrial firms in developing market economies acquire plant, equipment and technology, and technical mastery over each; and what can be done to speed the dissemination of economically superior and cleaner plant, equipment, and technology.[11] It also means that greater attention should be paid to the impact of policies in rich countries on the development of cost-effective cleaner technologies and on the scale and speed with which these cleaner technologies are diffused to poor countries.

For heuristic purposes, assume an MCCP given by the curve OAMCCP. Given the conventional marginal cost of abatement curve (MCA), the most cost-effective strategy for reducing pollution intensity in a firm, industry, or economy by QQ' requires firms or plants to reduce pollution intensity through end of pipe control by QB and to reduce pollution intensity through clean production by BQ'.[12] Note that, as drawn, most of the reduction comes from conventional end of pipe control. But is this really the most cost-effective way to reduce pollution

[7] This is particularly important for some pollutants like CO_2 that can not be abated by end of pipe technologies.

[8] But not all clean production pays either.

[9] A good example of the diffusion of a cleaner and economically superior technology can be found in Wheeler and Martin (1992).

[10] The World Bank recently estimated that between 1995 and 2010 new investment will account for 85% of total industrial capacity (Brandon and Ramankutty, 1993: 75).

[11] For an example of these effects in one industry see note 9.

[12] Note that, in this formulation, reductions in pollution intensity through reductions in energy and resource use intensity are incorporated in the area OQ'A.

(and energy and materials use) intensity? If there are no policy, coordination, and/or market failures in pollution, energy, materials, and technology markets, and if high transactions and learning costs do not inhibit the development of cost-effective cleaner production alternatives, the answer is yes.

But there are several reasons to suspect that policy, coordination, and market failures might be prevalent in clean technology markets. To begin with, it is well known that the “command and control” -oriented environmental agencies prevalent in the world tend to favor the use of BAT-based (or Best Available Clean Technology Not Entailing Excessive Cost—BACTNEEC) end of pipe technology standards over more flexible but uncertain clean production alternatives.[13] This bias, combined with increasingly stringent emissions standards, this may provide incentives for the end of pipe pollution control industry to search for cost-reducing end of pipe technological change. In terms of figure 1, biases in favor of end of pipe solutions to pollution have the effect of pushing MCA' down and to the right. Ceteris paribus, this biases cost-effectiveness toward more pollution intensity reduction by abating pollution after it has occurred.

But this is by no means the only policy failure; several others are common. Most prominent among these are pricing policies for energy and other materials. Frequently, energy prices are set below costs of production. Sometimes energy pricing policies also favor dirty over cleaner energy sources. When this happens, the marginal cost of clean production (OMCCP) curve is pushed up and to the right, pollution intensity reduction is biased in an end of pipe direction, and energy and materials intensities are higher than they would be under full-cost pricing.[14] Trade policy and other resource pricing policies can reinforce these effects if they protect inefficient resource processing activities. There is some evidence that this has occurred in Indonesia (Alberto and Braga, 1992: 190) and Malaysia (Vincent, 1993).

Coordination, information, and market failures can also increase the costs of clean production. Coordination failures can occur if individual firms that might mutually benefit from waste exchanges have no easy way of facilitating those exchanges (Ehrenfield and Gertler, 1997). Information failures can occur when, among other things, substitution of a less toxic input for a more toxic input is incorrectly perceived, either by producers or consumers, to reduce the quality of the final product (Laughlin and Corson, 1995:11). If producers act on this misperception, they forgo positive “dematerialization” and/or “pollution prevention” effects. This can also happen when intellectual property rights in new “dematerializing” technologies slow the diffusion of less energy and resource using technologies. Something like this appears to be occurring in high-technology plating activities.[15] And, as is well known, market failures can

[13] It is not difficult to understand why regulators gravitate in this direction. In a world of asymmetric information, where regulators and polluters distrust each other, best available end of pipe technologies provide relatively easy and less risky means for regulators to achieve easily verifiable and desired pollution intensity reductions.

[14] This may partially explain cross-country differences in energy use intensities within the OECD (Bernadini and Galli, 1993: 435) and Asia (Brandon and Ramnkutty, 1993: 99).

[15] Plating activities in the AMP Corporation are considered proprietary information. This includes those used to achieve zero emissions in a new plant recently built in China (interview with representatives of AMP Corporation in Singapore in December 1996).

occur when input and output market prices fail to reflect the true social cost of production and consumption.

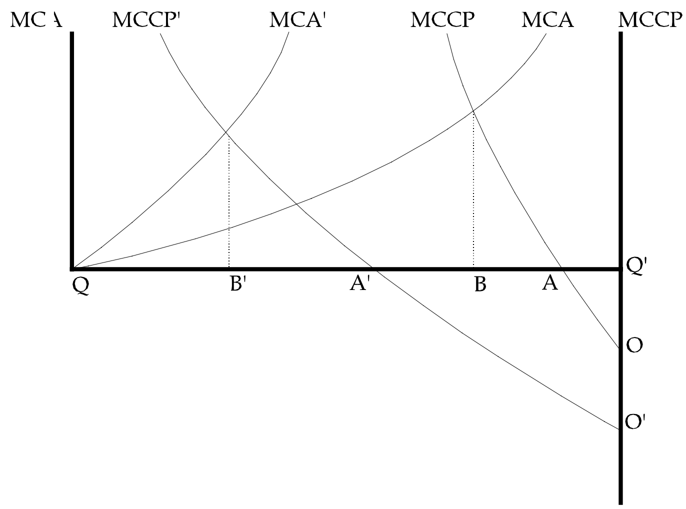
The biases of existing policy, coordination, and market failures may be reinforced by high transaction and learning costs particularly for unknown cleaner production alternatives. This may lead firms to continue using well-known end of pipe solutions rather than investing scarce managerial and engineering time and even scarcer capital in risky cleaner production alternatives (Panayotou and Zinnes, 1994). Since firms in developing countries depend overwhelmingly on firms in rich countries for plant, equipment, and technology—including environmental plant, equipment, and technology—high transaction and learning costs for cleaner technology alternatives to industrial-environmental management could well lead firms in poor countries to borrow well-known and proven end of pipe practices rather than invest in risky and unknown cleaner production alternatives.

The net impact of all of this on cost-effective pollution intensity reduction strategies can be seen by referring back to figure 1 (repeated below). If the regulatory policy bias against clean production were removed, the true marginal cost of abating pollution would be represented by curve MCA'. Overcoming policy failures, coordination, information and market failures, and high transaction and learning costs in cleaner technology has the effect of shifting the marginal cost of cleaner production curve (O'A'MCCP) down and to the left. Note that correcting policy, coordination, and market failures and overcoming high transaction and learning costs has several important effects on cost-effective pollution intensity reduction strategies. First, the range of clean production activities that pay (either through dematerialization or pollution prevention) expands from area OAQ' to area O'A'Q'. This provides more win-win opportunities for polluters. It may also convey Porter-like “competitive” advantages to firms that shift in this direction (Porter and van der Linde, 1995). Second, cost-effective reductions in pollution intensity require more clean production (an increase from B to B') and less end of pipe expenditure (a reduction from B to B'). Third, except in the case where the true O'A'MCCP' is less than the true MCA' for all levels of reduction in pollution intensity, firm- and plant-level cost-effective industrial-environmental management requires identifying the optimal combination of end of pipe and clean production. This is something that tends to get lost in the all-or-nothing debate over clean production.

Figure 1

Two other issues deserve mention. Virtually nothing is known about the relative size and impact of these policy, information, coordination, and market failures on cost-effective pollution intensity reduction strategies of industrial firms in rich or poor countries. The same can be said for transaction and learning costs. If these effects are small, the prevalence of end of pipe solutions may well be justified. But if they are large, it may justify intervention to correct these “failures” and to overcome high transaction and learning costs. In addition, it is conceivable that the size of these various effects may vary from one industry to the next and by pollutant. If this proved to be the case, it could provide justification for pollutant- and industry-specific interventions.

III. A Policy Menu for Cost-Effective Pollution, Energy, and Materials Use Intensity Reduction



So far, this simple but powerful analytical model suggests that cost-effective industrial pollution (and energy and materials use) intensity reduction strategies should focus on correcting policy, market, information, and coordination failures, and on reducing high transaction and learning costs, particularly for cleaner production alternatives. But what does this mean in practice? How can these admonitions be operationalized in a discrete policy menu? There is a simple and straightforward answer to this question. A policy menu for cost-effective pollution intensity reduction must focus on each of these issues: (1) the design of environmental regulatory policy; (2) the adoption of wide-ranging economic policies meant to take advantage of what will be referred to later as the "natural" process of dematerialization that appears to characterize long-term trends in market oriented economies; and (3) the adoption of policies that build on and take into account new investment policies and of technology policies on how firms in developing market economies acquire plant, equipment, and technology and how they gain mastery over this plant, equipment, and technology, including environmental technology.

A. The Design of Regulatory Policy

The design of environmental regulatory policies matters for two reasons.[16] First, the development of clear long-term environmental goals and the embedding of them in well-defined and agreed-upon quantitative pollution reduction targets is necessary to communicate to polluters that governments and the public are serious about reducing the pollution intensity of industrial production. Doing this requires enacting stringent environmental legislation; creating a strong, competent, and tough environmental agency; and empowering it to set, monitor, and enforce stringent emission standards.[17] Clear, consistent, and stringent emissions standards provide a

---

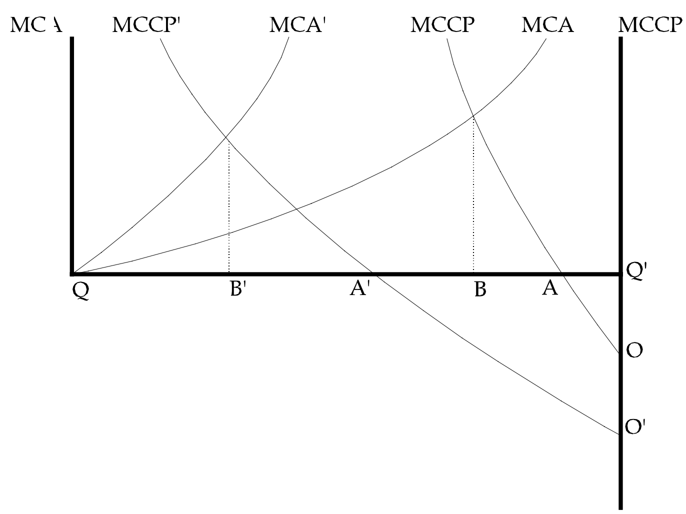
[16] Much of what follows is drawn from Rock (1997a).

[17] As is argued below, how this id done matters. Afsah, Laplante, and Wheeler (n.d.) Suggest that some of this can be accomplished when environmental agencies work in concert with communities and consumers to increase pressure on polluters. They also suggest that this does not mean creating a traditional command and control agency. What is important here is that environmental agencies have the capacity to set and enforce clear emissions standards.

firm base on which to build successful cost-effective pollution intensity reduction programs. In terms of figure 1 (repeated again for convenience), this means that public sector environmental agencies must have the capacity to set and enforce, by using credible sanctions, pollution intensity reduction targets such as QQ'.[18] Without this capacity, particularly without a credible threat to impose sanctions, reducing the pollution intensity of industrial production is likely to be all but impossible.[19]

But the specific policies and practices used by environmental agencies to set emissions standards and require firms to meet pollution intensity reduction targets matters.[20] If those policies rely on a traditional command and control approach that publicly imposes and mandates targets, encourages an adversarial relationship between polluters and regulators, and limits the flexibility of polluters to meet targets by mandating BAT or BACTNEEC technology standards for single media (air, water, and hazardous wastes), there is a strong chance that regulatory policy will bias intensity reduction in an end of pipe direction. In fact, much of the donor activity in Asia appears to be doing just that.

Figure 1



But this begs an additional question: what is the alternative? Recent innovations in OECD environmental policies suggest that an alternative might focus on five areas: (1) integrated pollution control (which emphasizes prevention and dematerialization); (2) greater public disclosure and public accountability for firm and facilities level pollution outcomes; (3) greater cooperation and trust between regulators and polluters in setting pollution reduction targets; (4) greater firm- and facilities-level flexibility in how those targets are met; and (5) use of market-based instruments such as pollution taxes, emissions charges, or tradeable permits to encourage firms to meet tough emission reduction goals.

Limited experience with innovative regulations in the OECD suggests what it takes to do these things well. Integrated pollution control programs require individual facilities to conduct

---

[18] This agency must also hava a mandate to revise pollution intensity reduction targets to take into account increases in the scale of economic activity.

[19] For a theoretical discussion of this issue see Ayres and Braithwaite (1992: 19-54).

[20] For a fuller discussion of these issues see Rock (1997a).

third-party environmental audits that identify all inputs; describe the production process; identify all pollutants by type and quantity; identify opportunities for pollution prevention and dematerialization; and set, in concert with regulatory agencies, quantitative and time bound facilities-specific pollution intensity reduction targets that embody a commitment to continuous improvement (Larkin, 1997). Regulators can hold polluters accountable to the public by requiring them to publicly report baseline pollution loads, baseline pollution intensities, and annual environmental performance relative to pollution intensity reduction targets (Arora and Cason, 1995). They can also use pollution taxes and/or emissions charges to entice them to meet proposed targets. Cooperation and trust between regulators and polluters and increased flexibility by firms can be achieved by relying on deliberative councils and/or voluntary pollution reduction agreements to set emissions reduction targets; by rewarding “good” performers with greater flexibility (Davies and Mazurek, 1996); and by engaging polluters and regulators in a collaborative search for cost-effective pollution intensity reduction options. One very intriguing example of how this has been done is a highly polluting industry in Malaysia (Vincent, 1993).

B. Building on the Processes Driving Long-Term Declines in Energy and Materials Use Intensities

The model developed in section II suggests that policies that encourage firms to reduce the energy and materials use intensities of production can be an important component of a clean production strategy. But what do we know about how to do this? There is now substantial evidence that energy and materials use intensities have declined, at least over long periods of time in rich countries. This is illustrated most clearly by energy use in the U.S., where there have been significant declines in the ratio of carbon emissions to energy use; the carbon intensity of GDP; and the energy intensity of GDP (Ausubel, 1996:5). Similar, if not as dramatic results, are observable in long-term trends in the materials use intensity of timber, steel, copper, zinc, lead (Warnick, Herman, Govind, and Ausubel, 1996: 17), and water (Rock, 1997b). The growing number of individual facility success stories with pollution prevention (Christensen and Georg, 1993; Nelson, 1994), toxic chemicals release reduction (Arora and Cason, 1995; Greiner, 1984), and the trend in the toxic chemicals intensity of GDP (Birdsall and Wheeler, 1992; Rock, 1996a) are very consistent with these developments.

But how pervasive are these dematerialization effects? Do they follow predictable patterns across countries and over time? What drives them? And, most important for the matters raised here, how might government policies designed to reduce the pollution intensity of industrial production and consumption build on and take into account these trends? Unfortunately, there are, as yet, no clear and convincing answers to these questions. Limited data availability, poor data quality, and incomplete theorizing continue to make empirical work in this area difficult.

Despite this, it is possible to piece together, for purposes addressed here, a coherent picture of dematerialization and the forces driving it. The point of departure is the growing evidence that pollution intensities (Birdsall and Wheeler, 1992; Rock, 1996a); water use intensities (Rock, 1997b); and intensities of use for energy, metals, and mineral ores follow a predictable inverted U curve (Bernadini and Galli, 1993) with respect to per capita income. That is, at the level of the economy as a whole, pollution intensities and intensities of resources use rise with increases in per capita income, reach a peak, and then decline. Across countries, peaks in intensity of use for energy, metals, and mineral ores occur at roughly similar per capita incomes. Peaks in intensity of use for energy and materials also occur at lower intensities of use for the late industrializers (developing countries). This combination has led some to suggest that global development might lead to global dematerialization (Warnick et al, 1995:194).

But what is driving these patterns? So far, the most reasonable explanations focus on: (1) changes in the composition of output attending growth in average incomes; (2) the normal competitive pressures among firms in market oriented economies that drive technical change in an energy and materials saving direction; (3) a country's initial factor endowments; (4) a wide range of economic policies; (5) the economics of recycling; and (6) the design of environmental policy.

Kuznets (1966), Chenery and Syrquin (1975), and Chenery (1979) have demonstrated that growth in average incomes is accompanied by predictable changes in the composition of output. At low levels of per capita income, most of GDP and employment are in low productivity, low intensity of energy and materials use agriculture. As development proceeds (as per capita incomes rise), the energy and materials intensity of agriculture rises (due largely to materials using infrastructure (roads and irrigation systems) and the use of oil- and mineral-based fertilizers). Output and employment also shift from lower pollution intensity and intensity of resources use agricultural activities to higher pollution intensity and intensity of resources use industrial activities. In addition, important shifts in the composition of industry affect the average pollution, energy, and materials intensity of the industrial sector (World Bank, 1994:78). This combination contributes to a rising pollution, energy, and materials intensity of GDP as incomes grow. But past some tipping point in average incomes, the agricultural and industrial shares of GDP fall; the pollution, energy, and materials intensity of industry falls as its composition changes; and the share of GDP in services, a less pollution, energy, and materials intensive sector, rises. With these shifts, the pollution, energy, and materials intensity of GDP peaks and then declines.[21]

But neither growth in per capita incomes nor changes in the composition of output occurs in a vacuum. Both are profoundly affected by the pace and scale of technical change, initial factor endowments, and public policy. We now know that technical change or total factor productivity (TFP)[22] growth is the ultimate driver of long-term income growth, changes in the sectoral composition of output (along with changes in demand), and declines in energy and materials use intensities. Stated most simply, increasing TFP requires doing more with less. It depends on the ability to substitute knowledge and experience (human capital) for physical labor, man-made capital (machines and man-made materials), and natural capital (energy and materials). Some have suggested that this means that the normal competitive pressures among firms in market-oriented economies drives technical change in an energy and materials use saving direction (Bernadini and Galli, 1993: 194).

[21] Declines in the pollution, energy, and materials intensity of GDP can also be hastened by environmental policies.

[22] Total factor productivity is an output per unit of all inputs (capital, labor, energy, and materials).

The histories of life cycles of individual energy and materials use in new and old (mature) products suggests how and why things might work out this way. Several examples should suffice.[23] New forms of energy (electricity, natural gas, and oil for home heating, for example) or new materials (aluminum, plastics, and fiberglass used in automobiles) are often introduced to solve old problems (the inconvenience and dirtiness of heating with coal, or the need to lower costs and improve fuel efficiency in automobiles). Most often these new forms of energy and materials have better properties than the materials they replace, and they often result in lower use intensities.

Initially, use of these new forms of energy or materials is low relative to output. As firms exploit these new materials by extending their use in new and old products, they also improve process technology to increase yields (i.e., lower intensities of use per unit of final product) and improve product quality. This combination can drive down intensities of use, result in lower product prices, and increase demand for products that use the new energy or materials. What this means is that for some time, consumption of the new form of energy or material increases faster than output and intensities of use rise. (While this is happening, intensity of use of older forms of energy (coal) and/or materials (carbon steel in automobiles) declines. But as market use of the new form of energy or material becomes saturated, use grows less quickly than output and intensity of use falls. This decline is frequently accelerated by the introduction of even newer forms of energy (atomic power for electricity) or materials (specialty steels for use in automobiles) that substitute for existing forms of energy and materials. There are countless examples of this and they have led,

> (some authors to conceive the process of technological change as oriented along a natural trajectory aiming for a long-term reduction in the use of resources. Bernadini and Galli, 1993:435).

If energy and materials use intensities were dominated by composition of output effects and resource-saving technical change, globalization might well put the world economy on a path to more sustainable industrial development. But clearly other things matter. For one, there are significant differences in energy and materials use intensities among countries with similar income levels. These differences cannot be attributed to either composition of output effects or technologically induced dematerialization effects. Some of this clearly has to do with initial factor endowments.[24] Some can be attributed to policy differences.[25] In addition, it is not clear that technical change is or always should be biased in a resource-saving direction. If it was, why are some materials use intensities rising,[26] and why have a substantial number of firms in rich

[23] What follows draws from Bernadini and Galli (1993: 436-436).

[24] Perhaps the most notable comparison is between Japan and the U.S. Japan is relatively natural resource-scarce and has a high population density, while the U.S. is relatively resource-rich and has low population density. Given this it is not surprising that Japan has a significantly lower energy intensity of GDP.

[25] Such as the price of primary energy.

[26] This is occurring for plastics, aluminum, phosphates, and potash.

countries forgone lucrative resource-saving (pollution prevention) opportunities until recently?[27] Part of the answer has to be that market-driven technical change depends on the relative prices of all inputs, not just resource inputs. What this means is that, despite the evidence on dematerialization, technical change may not always be biased in energy and materials savings directions.

At least one other issue clearly matters. Some part of the reduction in materials intensity of use is dependent on the economics of resource recovery.[28] Here consumer tastes (willingness to accept or to pay a premium for products with reprocessed materials), relative prices (of mining and of separating and recovering materials), technology, and environmental policies all matter. If consumers willingly accept products with reprocessed materials, or are willing to pay a premium for them, this provides more incentives for firms to use reprocessed rather than virgin materials. But whether this is actually done depends on comparing the cost of recovery to that of mining virgin materials. Sometimes the economics favors recovery (as in gold and silver recovery in circuit boards or lead in batteries) and sometimes it does not (platinum and cadmium recovery). Sometimes whether it does depends on the prevailing price of energy.[29] Sometimes it depends on the complexity of products and the relative difficulty of separating materials (as in cadmium recovery). If separation of materials is technically difficulty or time-consuming (as in complex consumer goods like automobiles), materials recovery becomes more expensive and can be slowed. Some have suggested that reconceptualizing products to emphasize functions alongside product take-back legislation might provide sufficient incentive for firms to design products in ways that reduce complexity and increase ease of separability of individual materials (Warnick and Ausubel, 1997: 9).

What does all of this mean for the design of policies to build on observed long-term tendencies toward dematerialization? The most straightforward answer is that it requires getting a wide range of economic policies right. This starts with getting resources prices right. When prices for energy and materials fall short of full costs, including environmental costs, as they often do, this encourages “excessive” use of energy and materials and discourages energy and materials savings. If sustained over long periods of time, this can bias technology in an energy and materials using direction. These effects can be exacerbated by inefficient concession agreements for resources-extractive (mining and logging) activities. This can encourage “excessive” extraction; artificially depress prices for metals, minerals, and logs; and thereby contribute to higher energy and materials use intensities by users of these raw materials. There is some evidence that this has happened in Indonesia and Malaysia. Correcting these policy failures by resorting to full-cost pricing and economically efficient concession agreements can

[27] If this weren't the case, pollution prevention would not so easily pay.

[28] What follows draws on Warnick et al, (1995: 183-85).

[29] This is particularly true for recycling aluminium.

send signals to firms to economize on energy and materials use. This may even induce energy- and resource-saving innovations.[30]

Exchange rate, trade, and investment policies also matter. Overvalued exchange rates and protective trade policies discriminate against exports while subsidizing production for the local market. There is some evidence that the protection afforded domestic producers by these policies can contribute to inefficient (that is, resource-processing activities with higher energy and materials use intensities than international best practice) resource-processing activities (Alberto and Braga, 1992: 190). In addition, lack of economic openness to trade and foreign investment can and has slowed the diffusion of economically superior and cleaner investment (Wheeler and Martin, 1992).

Industrial policies and policies affecting the allocation of credit can also affect the energy and materials use intensity of industrial production. As is well known, the heavy industry policies of the former Soviet Union and countries in Eastern Europe, and the bias against the services sector there, have resulted in higher intensities of metals use than observed elsewhere. Some of this is also visible in Japan and Korea, two countries that used explicit industrial policy, including administrative allocation of subsidized credit, to promote heavy and chemical industry drives.

One possible way to offset these biases against energy and materials savings activities in industrial and credit policies, is to build explicit environmental considerations into those policies. Experiences in Singapore, Malaysia, and Taiwan suggest how this might be done.[31] In each of these countries environmental considerations are being integrated with industrial promotion policies by fostering collaboration among environmental agencies, investment promotion agencies, the science and technology community, and commercial banks. Sometimes, as in Singapore, this requires investors seeking promotional privileges to identify all energy and material inputs, describe production processes, identify all pollutants by type and quantity, and propose a plan for meeting the country's tough emissions standards. Sometimes, as in Malaysia, it requires collaboration among polluters in one industry, the science and technology community, and an environmental agency to find cost-effective ways to reduce the pollution intensity of output. Sometimes, as in Taiwan, it takes the form of basic research on pollution, energy, and materials intensity of Taiwanese firms by a top-flight industrial technology research institute funded by the country's premier industrial policy agency. When promotional privileges, including access to subsidized credit, are conditioned on meeting tough emissions standards, when polluters and regulators work closely with the technology community to find cost-effective solutions to pollution intensity reduction, and when the industrial technology and industrial policy community begin to integrate environmental considerations into technology and industrial policy, industrial growth can be de-linked from pollution.[32]

[30] Induced innovations cite.

[31] For descriptions of this see Rock (1996c and 1996b).

[32] De-linking can be both relative and absolute. It is relative when pollution intensities fall and absolute when total pollution loads fall.

C. Enhancing the Capacity of Firms to Efficiently Manage Production and Technical Change

The design of environmental regulatory policy and policies to take advantage of the "natural" process of dematerialization in market-oriented economies is aimed at encouraging industrial firms in the DMEs of Asia to reduce the pollution, energy, and materials intensity of firm- (and plant-) level production. The capability to do this ultimately depends on existing firm- and plant-level technologies; the direction of technical change in those technologies (whether they are pollution, energy, and materials using or saving); and how successful firms are at efficiently managing plant, equipment, technology, technical change (especially technology acquisition), and technical know-how. If industrial firms in the DMEs lack the capability to use existing plant and equipment efficiently, to improve upon it and innovate with it, and/or to efficiently manage the process of technical change (and technology acquisition), there may be significant limits to their ability to respond to environmental and economy-wide policy incentives that would push them in a direction that lowers pollution, energy, and materials use intensities. Lack of capabilities in these areas might also limit the ability of firms to take advantage of new imported technologies that are cleaner than old or existing technologies.[33]

What do we know about the capabilities of firms in DMEs to manage production efficiently, carry out technical change, and manage the linkages with suppliers and buyers that ultimately contribute to improvements in production capabilities and in the capability to manage and carry out technical change?[34] There are several answers to these questions. First, there is enormous variability in the existing capabilities of firms to do this well (Roberts and Tybout, 1996). This capability varies by firm size, sector, and ownership. Large firms appear to be better at this than small firms (Lall, 1992: 169). This is easier for developing country firms to do in supplier-dominated capital goods sectors (textiles) than it is in either scale-intensive sectors (automobiles or aircraft) or science-based sectors (such as chemicals or electronics, where a strong capacity for reverse engineering is needed) (Bell and Pavitt, 1992: 265). Developing country firms engaged in joint ventures with large foreign firms appear to be better at this than domestically owned firms (Harrison, 1996: 167-173).

Second, because much of the acquisition of these capabilities is tacit—that is, it can only be gained from direct experience—variability also depends on a firm's willingness to invest in learning by doing in each of these areas (Bell and Pavitt, 1992: 262). There appears to be enormous variability in the willingness of firms to make these learning by doing investments. Moreover, this willingness can be strongly influenced by developing country policies. A stable high-growth environment appears particularly conducive to firms, willingness to invest in technological capability acquisition (Lall, 1992: 169). Trade policy also matters (Lall, 1992: 169).

---

[33] It might also limit their ability to adapt new imported technologies embedded in "new" investment that is more rather than less pollution, energy and/or materials intensive.

[34] Production capabilities refer to the ability to use plant, equipment, and technology to produce at international best practices level of efficiency with that technology. Technological capability refers to the ability within the firm to generate and manage technical change. Linkage capabilities refers to the ability to transmit and receive skills and technologies from suppliers and buyers that enable the firm to improve economic efficiency and the speed and spread of diffusion of new production and technological capabilities within the firm.

Efficient import substitution policies promote learning and making do with local capital, technology, know-how, and materials. In some cases, this has induced considerable “stretching” of locally available equipment. On the other hand, export-oriented industrialization policies require firms to reduce costs, raise quality, and introduce new products (Lall, 1992: 169). When this is tethered to lucrative export incentives, it can be a powerful stimulus to technical capability-building within firms (Rhee, Ross-Larson, and Pursell, 1984; Kim, 1997). State policies that favor and reward local firm technical capacity acquisition over reliance on foreign capital (direct foreign investment) can reinforce and have reinforced these effects (Mardon, 1990).

Third, because there are significant externalities in the accumulation of production, technology, and technology capabilities, government policies may be needed to speed the process by which firms acquire new technical capabilities and diffuse them throughout the economy. Experience in East and Southeast Asia suggest that two distinct sets of issues predominate. The first concerns the influence of government policy on firm size. The second concerns the need for government to invest in the provision of public goods that speed acquisition of technical capabilities in industrial firms.

With respect to the size of firms, two distinct patterns have emerged. In the Republic of Korea, one aim of government policy was to promote the development of very large firms that could internalize, and hence appropriate, many of the externalities associated with technological learning (Lall, 1992: 176; Jones and Sakong, 1980). When this was combined with stable and high growth, an export orientation, and an administrative structure that rewarded performance, the consequences for technical capabilities acquisition were enormous (Kim, 1997). Government support for the development of equally large industrial conglomerates in Indonesia and Malaysia suggests that something similar may be at work there (McVey, 1992; Rock, 1995). In Taiwan, industrial development policy promoted the establishment of a large number of small firms (Wade, 1990). Because none of these in any industry was capable of appropriating or internalizing the externalities associated with all facets of acquisition of technical capabilities, much of this was done by government, either in government-funded industrial technology research institutes or in coordinated government programs that managed technology imports, as well as the design, manufacture, and marketing of high technology products (DRAM chips) by several private firms (Lall, 1992: 176; Wade, 1990).

Public sector investments in national technical capability also matter. As the experiences of Korea and Taiwan demonstrate, large investments in literacy, secondary education, and tertiary education, particularly engineering training, make it easier for firms to acquire technical capabilities (Tan and Batra, 1995: 1, 7). A technology infrastructure that provides information (including information on cleaner technologies); tests materials; inspects and certifies quality control standards (including ISO 14000); calibrates measuring instruments (Tan and Batra, 1995); provides highly targeted and specialized training (World Bank, 1997) and highly targeted linkage programs between small and medium enterprises (SMEs) and foreign firms with international best practices (Battat, Frank, and Shen, 1996) can and does facilitate acquisition of production, technical, and marketing capabilities in SMEs. Providing these things also matters.

What are the implications of all of this for the pace and scale of diffusion within and between firms of production and technological capabilities in pollution, energy, and materials intensity reduction in the DMEs in Asia? There are three answers to this question. First, policies that promote firm-level technical learning and capabilities acquisition are likely to be good for pollution intensity reduction. They should make it easier for firms to engage in better housekeeping practices and minor process innovations that prevent pollution. Such policies should make it possible for firms to "stretch" existing plant and equipment by substantially modifying it to reduce pollution, energy, and materials use. They should also make it easier for firms to evaluate the pollution, energy, and materials intensity of "new" imported plant, equipment, and technology.

Second, because pollution, energy, and materials intensity reduction is or will be a relatively new activity for industrial firms in the DMEs, industrial firms in the DMEs are likely to need industry- and technology-specific information (and specialized technical training) on how to do this. This is the just the kind of information and specialized training that institutions that are part of the national technology infrastructure (such as industrial technology institutes or standards agencies) are good at providing. They should be encouraged to provide such information and training to overcome information failures and the high transaction costs associated with reducing pollution, energy, and materials intensities. This is most likely to be true for SMEs.

Third, existing SME/MNC linkage programs aimed at technological upgrading of SMEs might well be adapted for extending MNC "greening" the supply chain programs (Battat , Frank, and Shen, 1996). It may also make sense to consider developing such programs for large domestic firms and their suppliers.

IV. Summing Up

The arguments developed here suggest that getting environmental, economywide, industrial, and technology policies right is critical to getting individual industrial plants and the firms that own and manage them to undertake cost-effective pollution, energy, and materials intensity reduction.

Environmental policy must focus on two issues. First, governments must create and empower competent and tough environmental regulatory agencies that can set clear long-term environmental goals with well-defined and agreed-upon quantitative pollution reduction targets. In terms of the model developed in Section II (figure 1), this means that public sector environmental agencies must have the capacity to set and enforce, by using credible sanctions, pollution intensity reduction targets such as QQ'. Without this, particularly without a credible threat to impose sanctions, reducing the pollution intensity of industrial production is likely to be all but impossible.

Beyond this, environmental policies need to focus on: (a) integrated pollution control (with an emphasis on preventing pollution and continuous improvement); (b) public disclosure of plant- and firm-level baseline pollution intensities, baseline pollution intensity reduction targets, and annual plant- and firm-level performance relative to targets; (c) greater cooperation among polluters, regulators, and the science and technology community in the mutual setting of pollution intensity reduction targets and in the search for cost-effective technological solutions to pollution intensity; and (d) affording greater flexibility to firms, especially those where environmental performance is "beyond compliance," in how pollution intensity reduction targets are met.

Economywide, sectoral, and industrial policies for cost-effective pollution intensity reduction should emphasize: (a) full-cost pricing, including all social costs, for all forms of energy and materials use as well as for the manufacture, use, and disposal of all products; (b) economically efficient concession agreements between governments and resource extractive industries; (c) market-oriented exchange rate and trade policies for achieving efficient energy use in all industries and for achieving efficient (international best practice) materials use for all materials-processing activities; and (d) the integration of environmental considerations in industrial policies. Experiences in Singapore, Taiwan, and Malaysia suggest that this integration can be done by fostering collaboration among environmental agencies, investment promotion agencies, the science and technology community, and commercial banks.

But none of this will work unless individual plants, factories, and firms have or acquire the capacity to efficiently manage production at international best practice levels and to efficiently manage technical change, particularly that associated with the acquisition and adaptation of new imported technology. Evidence abounds that there is enormous variation among firms and across sectors and countries in the ability to do these things and do them well. Yet, unless firms do these things and do them well, they are unlikely to engage in cost-effective pollution intensity reduction by: (a) carrying out better housekeeping practices and minor process innovations that prevent pollution; (b) "stretching" existing plant, equipment, and technology by substantially modifying it to reduce pollution, energy, and materials use; and (c) correctly evaluating the pollution, energy, and materials intensity of “new” imported plant, equipment, and technology.

Because of this, governments need to promote the development of firm-level production and technological capabilities, including those associated with environmental improvement. They can do this by promoting high stable growth and the export of manufactures, and by either promoting the development of large firms that can internalize the externalities associated with technological learning (the Korean experience) or relying on a collaborative relationship between business and government to reap these externalities (the Taiwanese experience).

In either case, governments must also invest in national technical capabilities-building by supporting education, particularly engineering (and environmental engineering) education, and by investing in institutions that can test materials, inspect and certify quality control standards (including environmental standards such as ISO 14000), calibrate measuring instruments, and provide difficult to obtain information (including in the area of clean technologies). Because of the unique problems of small and medium enterprises (SMEs), governments might also consider building environmental considerations into already existing or is new and to be developed highly targeted linkage programs between SMEs and foreign firms with international best practices.

One other issue matters. Knowledge in each of these areas is extremely limited. Because of this, it is important to proceed by trial and error and to engage in a substantial applied research program. Without this research program, there is enormous potential to waste scarce resources and to miss an important opportunity to assist the DMEs in Asia in making a transition to a less pollution, energy, and materials intensive industrial growth path. This would be extremely unfortunate.

References

Afsah, S., Laplante, B., and Wheeler, D. n.d. "Controlling Industrial Pollution: A New Paradigm." Washington, D.C.: World Bank.

Alberta, C. and Braga, P. 1992. "Tropical Forests and Trade Policy: The Case of Indonesia and Brazil." in Low, P. (ed.) *International Trade and the Environment*. Washington, D.C.: World Bank. 173-94.

Arora, S., and Cason, T. 1995. "An Experiment in Voluntary Environmental Regulation: Participation in EPA's 33/50 Program." *Journal of Environmental Economics and Management.* 28: 217-86.

Ausubel, J. H. 1996. "The Liberation of the Environment." *Daedalus* 125 (3): 1-18.

Ayres, I., and Braithwaite, J. 1992. *Responsive Regulation*. New York: Oxford University Press.

Battat, J., Frank, I., and Shen, X. 1996. "Suppliers to MNCs: Linkage Programs to Strengthen Local Companies in Developing Countries." Foreign Investment Advisory Service: Occasional Paper No. 6. Washington, D.C.: World Bank.

Becker, M., and Geiser, K. 1997. Evaluating Progress: A Report on the Findings of the Massachusetts Toxics Use Reduction Program Evaluation. Boston: Massachusetts Toxics Use Reduction Program.

Bell, M., and Pavitt, K. 1992. "Accumulating Technological Capability in Developing Countries." in *Proceedings of the World Bank Annual Conference on Development Economics*. Washington, D.C.: World Bank. 257-81.

Bernadini, O., and Galli, R. 1993. "Dematerialization: Long-Term Trends in the Intensity of Use of Materials and Energy." *Futures*. May: 431-48.

Birdsall, N., and Wheeler, D. 1992. "Trade Policy and Industrial Pollution in Latin America: Where are the Pollution Havens?" in Low, P. (ed.) *International Trade and the Environment*. Washington, D.C.: World Bank. 159-68.

Brandon, C., and Ramankutty, R. 1993. *Toward an Environmental Strategy for Asia*. Discussion Paper No. 224. Washington, D.C.: World Bank.

Beardsley, D. 1996. *Incentives for Environmental Improvement: An Assessment of Selective Innovative Programs in the States and Europe*. Washington, D.C.: GEMI.

Chenery, H., and Syrquin, M., 1975. *Patterns of Development: 1950-1970.* London: Oxford University Press.

Chenery, H. 1979. *Structural Change and Development Policy*. Baltimore: Johns Hopkins University Press.

Christensen, P., and Georg, S. 1994. “Regulatory Effects in the Electroplating Industry: A Case Study in Denmark.” Journal of Cleaner Production. 3 (4): 221-23.

Christiansen, K., Nielsen, B. Doelman, P., and Schelleman. 1995. “Cleaner Technologies in Europe.” *Journal of Cleaner Production* 3 (1-2): 67-70.

Davies, T., and Mazurek, J. 1996. *Industry Incentives for Environmental Improvement: Evaluation of U.S. Federal Initiatives*. Washington, D.C.: GEMI.

Ehrenfield, J., and Gertler, N. 1997. “Industrial Ecology in Practice: The Evolution of Interdependence at Kaolundborg.” *Journal of Industrial Ecology* 1 (1): 67-97.

Friedlander, S.K. 1989. “Environmental Issues: Implications for Engineering Design.” in Ausubel, J.H. and Sladovich, H.E. (eds.). *Technology and the Environment*. Washington, D.C.: National Academy Press.

Frosch, R. 1996. “Toward the End of Waste: Reflections on a New Ecology of Industry.” *Daedalus* 125 (3): 199-211.

Greiner, T. 1984. “The Environmental Manager's Perspective on Toxics Use Reduction Planning.” M.S. Thesis. Boston: Massachusetts Institute of Technology.

Grubler, A. 1996. “Time for A Change: On the Patterns of Diffusion of Innovation.” *Daedalus* 125 (3): 19-41.

Harrison, A. 1996. “Determinants and Effects of Direct Foreign Investment in Cote d'Ivoire, Morocco, and Venezuela.” in Roberts, M., and Tybout, J. (eds.) 1996. *Industrial Evolution in Developing Countries*. New York: Oxford University Press. 163-86.

Heaton, G. 1997. “Toward a New Generation of Environmental Technology.” *Journal of Industrial Ecology* 1 (2): 23-32.

Hersh, R. 1996. *A Review of Integrated Pollution Control in Selected Countries*. Discussion Paper 97-17. Washington, D.C.: Resources for the Future.

Hettige, H., Huq, M. Pargal, S., and Wheeler, D. 1996. “Determinants of Pollution Abatement in Developing Countries: Evidence from South and South East Asia.” *World Development* 24(12): 1891-1904.

Hone, A. 1974. “Multinational Corporations and Multinational Buying Groups: Their Impact on the Growth of Asia's Exports of Manufactures.” *World Development*. 2 (2): 147-53.

Jones, L., and Sakong, I. 1980. *Government, Business, and Entrepreneurship: The Korean Case*. Cambridge, Mass.: Harvard University Press.

Kim, L. 1997. *From Imitation to Innovation*. Boston: Harvard Business School Press.

Kuznets, S. 1966. *Modern Economic Growth: Rate, Structure, and Spread*. New Haven: Yale University Press.

Lall, S. 1992. "Technological Capabilities and Industrialization." *World Development* 20 (2): 165-82.

Larkin, P. September 15, 1997. "Environmental Management in Ireland." Presentation made at Workshop on Downstream Environmental Management. Washington, D.C.: The World Bank.

Laughlin, J., and Corson, L. 1995. "A Market-based Approach to Fostering P2." *Pollution Prevention Review* 11-16.

Mardon, R. 1990. "The State and the Effective Control of Foreign Capital." *World Politics* 43 (October): 111-38.

McVey, R. (ed.) 1992. *Southeast Asian Capitalists*. Ithaca: Cornell University Press.

Nakicenovic, N. 1996. "Freeing Energy from Carbon." *Daedalus* 125 (3): 95-112.

Nelson, K. 1994. "Funding and Implementing Projects That Reduce Waste" in Scolow, R., Andrews, C. Berkhout, F., and Thomas, V. (eds.). *Industrial Ecology and Global Change*. Cambridge: Cambridge University Press. 371-82.

Nelson, R.R. (ed.) 1993. *National Innovation Systems: A Comparative Analysis*. New York: Oxford University Press.

Panayotou, T., and Zinnes, C. 1994. "Free Lunch Economics for Industrial Ecologists." in Scolow, R., Andrews, C., Berkhout, F., and Thomas, V. (eds.). *Industrial Ecology and Global Change*. Cambridge: Cambridge University Press. 383-97.

Porter, M., and van der Linde, C. 1995. "Toward a New Conception of the Environment-Competitiveness Relationship." *Journal of Economic Perspectives* 9 (4): 97-118.

Rhee, Y., Ross-Larson, B., and Pursell, G. 1984. *Korea's Competitive Edge: Managing Entry into World Markets*. Baltimore: Johns Hopkins University Press.

Roberts, M., and Tybout, J. (ed.) 1996. *Industrial Evolution in Developing Countries*. New York: Oxford University Press.

Rock, M. 1997a. “Experiences with Public Sector Clean Technology Programs in the OECD: Implications for Clean Technology Policy in Rapidly Industrializing Asia.” Washington, D.C.: US-Asia Environmental Partnership.

--------., 1997b. “Freshwater Use, Freshwater Scarcity and Socio-Economic development.” paper under review by *Journal of Environment and Development.*

-------., 1997c. “Industry and the Environment in Ten Asian Countries: Synthesis Report of USAEP Country Assessments.” Washington, D.C.: US-Asia Environmental partnership.

-------., 1996a. “Pollution Intensity of GDP and Trade Policy: Can the World Bank Be Wrong?” *World Development* 24(3): 471-79.

-------., 1996b. “Toward More Sustainable Development: The Environment and Industrial Policy in Taiwan.” *Development Policy Review* 14(3): 255-72.

-------., 1995. “Thai Industrial Policy: How Irrelevant was It to Export Success?” *Journal of International Development* 7 (5): 745-57.

Tan, H. A., and Batra, G. 1995. “Enterprise Training in Developing Countries: Incidence, Productivity Effects, and Policy Implications.” Private Sector Development Department. Washington, D.C.: World Bank.

Vincent, J. 1993. “Reducing Effluent While Raising Affluence: Water Pollution Abatement in Malaysia.” Boston: Harvard Institute for International Development.

Wade, R. 1990. *Governing the Market*. Princeton: Princeton University Press.

Warnick, I. , Herman, R., Govind, S, and Ausubel, J. 1996. “Materialization and De-materialization: Measures and Trends.” *Daedalus* 125 (3): 171-98.

Warnick, I., and Ausubel, J. 1997. “Industrial Ecology: Some Directions for Research.” Mimeo. New York: Rockefeller University.

Watanabe, C. 1995. “Mitigating Global Warming by Substituting Technology for Energy: MITI's Efforts and New Approach.” *Energy Policy* 23 (4/5): 447-61.

Westphal, L., Rhee, Y., and Pursell, G. 1981. *Korean Industrial Competence: Where It Came From*. World Bank Staff Working Paper No. 469. Washington, D.C.: World Bank.

Wheeler, D., and Martin, P. 1992. “Prices, Policies and the International Diffusion of Clean Technology: The Case of Wood Pulp Production.” in Low, P. (ed.). *International Trade and the Environment*. Washington, D.C.: World Bank.

World Bank. 1994. *Indonesia: Environment and Development*. Washington, D.C.: World Bank.

________. 1997. *Malaysia: Enterprise Training, Technology, and Productivity*. Washington, D.C.: World Bank.